EFFECT OF NANOPARTICLES ON THE VAPOR COMPRESSION REFRIGERATION SYSTEM – A REVIEW

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Abstract: Nanolubricants are a unique type of nanofluids which are mixtures of nanoparticles and refrigerants and have a wide range of applications in various fields for case in point refrigeration, air conditioning systems, and heat pumps. In this paper thermal–physical properties of nanolubricants suspended in refrigerant and lubricating oils of refrigerating systems were reviewed. Based on results available in the literatures, it has been found that nanorefrigerants have a much higher and strongly temperature-dependent thermal conductivity at very low particle concentrations than conventional refrigerant. This can be considered as one of the key parameters for enhanced performance for refrigeration and air conditioning systems. Because of its superior thermal performances, latest up to date literatures on this property have been summarized and presented in this paper as well. The results indicate that HFC134a and mineral oil with TiO2 nanoparticles work normally and safely in the refrigerator with better performance. The energy consumption of the HFC134a refrigerant using mineral oil and nanoparticles mixture as lubricant saved 26.1% energy with 0.1% mass fraction TiO2 nanoparticles compared to the HFC134a and POE oil system.

***IndexTerms* – Nanoparticles, nanolubricant, Nanorefigeration, Coefficient of Performance.**

I. INTRODUCTION

It is well known fact that conventional fluids such as water, ethylene glycol (EG) and engine oils have low thermal conductivity and the efficiency of heat transfer with a very small temperature difference is limited. There is a need for energy efficient working fluids to improve the energy conversion system. However, the coefficient of convective heat transfer depends on thermal conductivity of the fluid. The conductivity of fluid is improved by adding micrometer or millimeter sized solid materials to the base fluids. The solid additives improve the thermal conductivity of the base fluid. The practical applications are limited due to the clogging of flow channels, sedimentation of large particles and causing pressure drops. The above drawbacks are overwhelmed by using a new class of fluids called nanofluids. Choi in Argonne National Laboratory introduced the concept of nanofluids. Nanofluids are a new class of solid-liquid composite materials consisting of solid nanoparticles (in the range of 1-100 nm) or carbon nanotubes, dispersed in a heat transfer fluid such as ethylene glycol, water or oil.

1.1 As a Nanolubricant:

Sheng- shan Bi, Lin shi, Li- li Zhang (2008) stated that the refrigerator system worked normally and efficiently when the mineral oil with TiO2 nanoparticles of 50 nm average particle diameter is used as a lubricant. The mass concentration was about 0.1%. The energy consumption was observed to be lowered by 26.1% when compared with the system with HFC134a- POE oil. [1]

Satnam Singh, Kapil Sharma, Kundan Lal, Naveen Mani Tripathi (2015) have found that the addition of Al2O3 nanoparticles to the refrigerator lubricant, Polyol-ester (POE) oil at 0.2% mass concentration resulted the decrease in the friction coefficient by 90% with the overall increase in the system efficiency. The results also revealed that the addition of nanoparticles increases the critical heat flux. [2]

R.Santhanakrishna & V.Shanmugam (2016) has done the preparation and property analysis has done on the ZrO2 based nanolubricant for a VCR. The structural and chemical characterizations of nanolubricant were performed by Scanning Electron Microscope (SEM), X- Ray Diffraction (XRD). ZrO2 nanoparticles dispersed in oil at various concentrations of 0.1, 0.2 and 0.3 vol. %. Ultrasonic vibration was used to stabilize the dispersion of the nanoparticles. The results showed that viscosity of nano lubricant oil is more than that of the pure oil and it is observed that the thermal conductivity increases with the addition of nanoparticles. [4]

T.M. Yusof, A.M. Arshad (2015) has found that the experimental study was done on a domestic refrigerator with Al2O3-POE nanolubricant. The Al2O3 nanoparticles were mixed with Polyolester (POE) lubricant to form nanolubricant at 0.2% concentration by volume. The results showed that the energy consumption of the refrigeration system with POE-Al2O3 at optimum refrigerant charge was the minimum and maximum COP of 321Wh and 2.67. The highest percentage of energy consumption reduction was 2.1% at optimum refrigerant charge. [7]

M.E.Haque, R.A.Bakar (2016) has done the performance of a domestic refrigerator was analyzed with TiO2- POE and Al2O3- POE Nanolubricants. The nanoparticles concentration was about 0.05% and 0.1%. The mixtures were then kept vibrating in an ultrasonic homogenizer for half an hour to fully separate the nanoparticles and to prevent agglomeration and sedimentation of particles. The results revealed that the POE oil containing 0.1% TiO2 to reduce the cooling load temperature from 10 °C to -7 °C, which is 50% less than the pure POE oil system. Result also shows the freezing capacity of 0.05% of Al2O3 is 60% less than the pure POE oil system. [8]

D. Senthilkumar (2017) stated that the refrigeration system was analyzed with the Al2O3 nanopowder- PAG(Polyalkylene Glycol) oil used as nanolubricant in the refrigerator system working with R134a refrigerant. The volume percentile was about 0.2%. The performance of the system was found out using energy consumption test and freeze capacity test. The results showed that the performance was better than pure lubricant with R134a working fluid with 10.32% less energy and also heat transfer coefficient increases with the usage Al2O3 nanopowder. The COP of the nano Al2O3 refrigerant system increases by 15%.[9]

Yongjian Gaoa, Guoxu Chena, YaOlib (2001) said that the property analysis was carried on the tribological properties of Oleic acid modified- modified TiO2 nanoparticles in water. cis- 9- octadecenoic acid (OA), CH3(CH2)7CH=CH(CH2)7CO2H, surface-modified TiO2 nanoparticle was synthesized using a sol–gel method, and its tribological properties in water were inestigated using a four ball tester. The fluid posses excellent load carrying capacity, good investigated using a four-ball tester. The fluid posses excellent load-carrying capacity, good extreme pressure, anti wear and friction reduction properties at boundary lubrication condition in water. [10]

Vaishali p. Mohod, Nishikant w. kale (2017) stated that the vapour compression refrigeration system works normally and safely with the Al_2O_3 nanolubricant. Stable nanolubricant has been prepared with VG68 Polyolester oil for the study. Three different mass concentrations 0.04%, 0.06% and 0.08% of Al2O3 nanoparticles with 20 nm size has been used for the study. The results indicate that refrigeration system with nanorefrigerant works normally and safely. It is found that the freezing capacity is higher and power consumption reduces by 14.71% and the coefficient of performance increases by 28.93% [12]

M.S.Bandgar, R. N. Kare (2016) has done an experimental investigation was carried out on a vapour compression refrigeration system working with the SiO_2- POE(polyolester)/ SiO_2- mineral oil nanolubricant and R600a as the working fluid. Investigation was done on the compatibility of POE/Mineral oil mixed with Silica (SiO2) Nano powder (at a concentration of 0.5%, 1% and 1.5% by mass fraction). The results showed that at mass fraction of 0.5% for all combinations of Nano-oils. It was found that the time required reducing the temperature of water to 10℃ is less and the power consumption reduces by 12.02% when POE oil is replaced by a mixture of (MO+ 0.5% Silica). It has been observed that C.O.P. is increased by 11.66% when POE is replaced by a Nanolubricant (mineral oil + 0.5% of SiO2). [13]

Nilesh S. Desai and P.R.Patil (2015) stated that the vapour compression refrigeration system worked safely and normally with the SiO_2- mineral oil nanolubricant. The nanoparticles were steadily suspended in the mineral oil at a stationary condition for long period of time. The result shows the COP of system were improved by 7.61%, 14.05% & 11.90%, respectively, when the nano- oil was used instead of pure oil. [14]

Dr. K.Dilip Kumar, T.Ayyappahas (2016) done an experimental study was carried out on a vapour compression refrigeration system working with the Al_2O_3- POE nanolubricant. The nanooil was prepared with specific concentrations of 1.5%, 1.7% and 1.9 %(by mass fraction). The result shows the COP of system were improved by 19.14%, 21.6% & 11.22%, respectively, when the nano- oil was used instead of pure oil. The thermal conductivities of nanorefrigerant are higher than traditional refrigerants. From the experimental investigations Actual COP is increased up to 21.6% at 1.7%.mass concentration. After that it decreases so optimum percentage is 1.7% of Al2O3 for given 0.06 TR systems. [15]

WU Di, LIU Shi (2014) has done a vapour compression refrigeration system performance was analyzed with the addition of Ag nanoparticles and CNT in the refrigerator lubricant. The optimal amount is 4 mg/L CNT in nano-fluid. Ag/carbon nano-tube (CNT)/water nanofluids were prepared by dispersing Ag nanoparticles and CNT into water as a base fluid. The solution was kept stirring for another 5 min and then filtered to remove any un-dissolved impurities. The resultant solution was centrifuged at a speed of 14000 rpm. With the addition of a small amount of Ag NPs in the pure water, the efficiency under the same conditions was ranked as PVP/ Ag > L-cys/ Ag > PAN/ Ag > OA/ Ag. Adding a small amount of CNT in the mixture, the effect was enhanced further. As more CNT became dispersed in the working fluid, the opposite effect was observed. [16]

Jayendra, Sanket, Sagar(2017) has done an experimental study was carried out on the performance of a vapour compression refrigeration system working with Al_2O_3- mineral oil nanolubricant. The mass fraction of nanoparticles in lubricant was 0.06%. This study indicates that the power consumption of compressor is decreased by 11.5% and the freezing capacity is also higher. The coefficient of performance of the system also increased by 19.6% when POE oil changed with mixture of nanoparticles mineral oil. [17]

R. KAdyanshee Pattanayak, Nilamani Sahoo (2015), in an experimental investigation, the desired amount of Al_2O_3 nanoparticles are added to the PAG (Polyalkyle Glycol) lubricant oil and for even distribution of nanoparticles in the lubricant oil, the mixture (PAG oil and nanoparticles) has to place in an ultrasonic vibrator for 6-7 hours. The power consumption of the compressor was reduced by 10%, 20% and 26.6% and the coefficient of performance of the refrigerating system was improved by 12.14%, 27.8% and 39.46% for mass fractions of 0.47%, 0.952% and 1.42% of Al_2O_3 nanoparticles. [18]

D. Sendil Kumar & Dr. R. Elansezhian (2012), The experimental investigation was carried out on a VCR system where Nano Al2O3-PAG oil was used as nano-refrigerant in R134a vapour compression refrigeration system. The nanoparticles of Al_2O_3 in the range 40-50 nm were mixed with PAG to synthesize nanolubricant in a recommended method for nanofluid. The results were showed that the addition of Nano Al_2O_3 in to the refrigerant is to improvement in the COP of the refrigeration system. Usage for Nano refrigerant reduces the length of capillary tube and cost effective. [19]

Damola S. Adelekana, Olayinka S. Ohunakina, Taiwo O. Babarinde (2016), The experimental investigation is carried out of varied mass charges of Liquefied Petroleum Gas (40 g, 50 g, 60 g and 70 g) enhanced with varied TiO2 Nanoparticle/mineral oil concentrations(0.2 g/L, 0.4 g/L and 0.6 g/L nano-lubricants) in a R134a compressor of a domestic refrigerator. The TiO2 nanoparticles (15 nm size, 99.7% in purity, and produced by Alfa Aesar) in the range of 0.0001–110 g are added to a measured volume of mineral compressor oil. The results showed almost equal evaporator air temperatures and reduction in power consumption for all tested nano-lubricant concentrations except at 70 g charge of LPG using 0.6g/L nano-lubricant. [23]

M. S. Bandgar, Dr. K. P. Kolhe& Dr. S. S. Ragit (2016), An investigation was done on the compatibility of POE/Mineral oil mixed with Silica (SiO2) Nano powder (at a concentration of 0.5%, 1% and 1.5% by mass fraction) as Nano lubricant. The refrigeration system performance with the Nano lubricant was investigated by using energy consumption and refrigeration effect test. The results were showed that the increase in COP is 4.39% when POE oil is replaced with mineral oil. It is found that the VCR system using (Mineral oil+0.5%SiO_2) as lubricant has highest COP. When Nano lubricant (0.5% SiO_2 + Mineral oil) is used instead of pure mineral oil then COP is increased by 12.61%. [24]

Mohammed Ajmal A, Sunir Majilya (2017) has investigated the influence of CuO nanoparticles on the tribological characteristics of Polyolester (POE) oil is experimentally investigated and Surface roughness, viscosity were studied. Three different mass fractions of nanoparticles 0.025%, 05% & 0.1% are dispersed with 50 ml of POE oil. Each sample is kept under ultrasonic agitation process for 60 minutes. The results were showed that the potential of nanolubricants in reducing the friction coefficient compare to that of the pure lubricant. The friction coefficient as 0.18, 0.13, 0.09 & 0.06 for nanoparticles of 0.025%, 0.05% & 0.1% in POE oil. [25]

R. K. Adyanshee Pattanayak, Prasheet Mishra (2016), the experimental investigation is carried out by the use of nano fluid in enhancement of the performance of a domestic refrigerator. The amount of nanoparticles are added with the mineral oil and for uniform distribution of the nanoparticles in the oil, the mixture (Mineral oil and nanoparticles) is placed in an ultrasonic vibrator for 6-7 hours. The nanofluid prepared is of the mass fraction of 0.2% & 0.5% respectively. The results were showed For 0.2%, 0.4% mass fraction of nanoparticles, the coefficient of performance of the system increases by 7.75% & 14.48% for PAG oil and 19.38% & 25.3%for mineral oil respectively. [27]

1.2 As a Nanorefrigerant

Tarun Sharma, Kundan Lal Rana (2015), The experimental investigation was carried out on a refrigerator system working with nanorefrigerant of Al_2O_3- R134a. The nanoparticles of Al_2O_3 of (1- 100 nm) are suspended in the conventional R134a. The results showed that the refrigerator takes less time achieve desired temperature than with pure refrigerant. [3]

V.P.Suresh Kumar, A.Baskaran&K.ManikandanSubaramanian (2016), The experimental investigation was carried out on R134a refrigeration system by using ZrO_2 nanoparticles with R152a refrigerant. The concentration of nano ZrO_2 particles was about 0.01% and 0.06% by volume. The average particle size is 20nm. The ZrO_2- R152a nanorefrigerant was used as the working fluid. The results showed that the coefficient of performance of the system was significantly improved with 33.45% when 0.06% volume concentration of ZrO_2 with R152a refrigerant was used. [5]

K.T. Pawale, A. H. Dhumal& G. M. Kerkal (2017) stated that the Nano-particles can be used along with refrigerant in order to improve the performance of vapour compression refrigeration system. Alumina (Al_2O_3) nanoparticles of 50mm diameter are dispersed in refrigerant R134a. The results in this experiment showed that R134a+0.5% Al_2O_3 nanorefrigerant resulted in the improvement of actual COP by 30.85% and R134a+1% Al_2O_3 showed the decline in actual COP by around 8.55%. [6]

TumuluriKanthimathi, ArimandaTeja, DandamudiPardhaSaradhi (2017), The heat transfer characteristics of R134a refrigerant were enhanced with the Al_2O_3 nanoparticles. The analysis is carried out at the room temperature of 25 degrees Celsius for the volume concentrations of 0.05%, 0.07%, 0.1%, 0.5%, 1% respectively. The results showed that as the volume concentrations are increasing, the Specific heat of the nano refrigerant is decreasing and the Thermal Conductivity is increasing. [11]

Praveshkumarkushwaha, Pavan shrivastava& Ashish kumarshrivastava(2016), The performance of the refrigeration system is investigated with pure refrigerant R134a. After that the system was charged with nanorefrigerant R134a + Al2O3 with 0.25 gm mass and 0.50 gm mass of nanoparticles. Then performance is investigated with the Al2O3 nanoparticles. The results are showed that with refrigerant R134a + 0.25% Al2O3 and refrigerant R134a + 0.50% Al2O3 improvement in performance is upto 11.76% as compared to refrigerant R134a. [20]

Balwant Kumar Singh & Md. Shahnawaz Ansari (2017), The experimental investigation is carried out on the performance of a VCR system with the pure hydrocarbon refrigerant is compared with the nanorefrigerant in which different volumetric concentrations of CuO nanoparticles are mixed with hydrocarbon refrigerant in vapour compression refrigeration system. Cupric Oxide(CuO) nanoparticles of size (20-30) nm has been taken and three different volumetric concentrations (0.15, 0.25, 0.35) gm of CuO were being used in this refrigeration system. The results showed that there is improvement in COP of the system by 3.18% to 11.57 % and energy consumption reduces by 13.5% to 19.7% due to usage of nanorefrigerant. [21]

T. Coumaressin, K. Palaniradja., R. Prakash (2015), The performance of a vapour compression refrigeration system was enhanced with Aluminum oxide and copper oxide nano fluids used with R134a refrigerant. The heat transfer coefficient and performance of the system were evaluated by using TK Solver, using nano concentration 0 to 1%. The experimental investigation results were showed that the heat transfer and performance characteristics of the system is higher with the usage of Al2O3 nano particles with R134a refrigerant compared to CuO nanoparticles. [22]

A.Senthilkumar, R.Praveen (2016), The experimental investigation is carried out on a vapour compression refrigeration system and it uses natural gas to enhance the energy efficiency of refrigeration retorting method employing CuO-R600a as alternating refrigerants. A performance test is made for the pure R600a system firstly, and then CuO- R600a with different concentrations of nano particles was put into the refrigeration systems again under the same condition. The results showed that that CuO- R600a can work normally and efficiently in refrigerator. Combined with refrigerator using pure R600a as working fluids. 0.1 & 0.5g/L concentrations of CuO - R600a can save 11.83% and 17.88% energy consumption respectively and the freezing velocity of CuO - R600a was more quickly than the pure R600a system. [26]

CONCLUSION

Most of the studies on the mixture of nanoparticles and refrigerants in the literature are summarized in this study. Due to their enhanced heat transfer characteristics, it is expected that nanorefrigerants will be used in many domestic and industrial devices in the near future. The following remarks can be extracted from the present review:

1. CNTs can be considered as a promising passive heat transfer enhancement additive in comparison with the spherical nanoparticles of Al, Si, Ti, Cu, diamond, and their oxide versions.
2. Energy consumption can be reduced by using nanorefrigerants.
3. As a result of some investigations, it is reported that the freezing speed and COP in cooling devices are improved by adding nanoparticles to the refrigerants.
4. The lubricant type has the potential to enhance the heat transfer rate.
5. The surfactant type has the potential to eliminate the problems of nanoparticles regarding their extended usage

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